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Tsunamis: Monitoring, Detection, and Early Warning Systems

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Tsunamis: Monitoring, Detection, and Early Warning Systems

Summary

Some in Congress are concerned about the possible vulnerability of U.S. coastal areas to tsunamis, and about the adequacy of early warning for coastal areas of the western Atlantic Ocean. This stems from the December 26, 2004, tsunami that devastated many coastal areas around the northern Indian Ocean, where few tsunami early warning systems currently operate. The tsunami was caused by a strong underwater earthquake off the coast of Sumatra, Indonesia. The earthquake and tsunami together are estimated to have claimed as many as 300,000 lives. Affected nations, assisted by others, are pursuing multilateral efforts through the UNESCO Intergovernmental Oceanographic Commission (IOC) to develop a regional tsunami detection and warning network that would guard coastal populations around the Indian Ocean. Those efforts would coincide with the United States' goal of upgrading and expanding its tsunami detection and early warning network.

Some developed countries bounding the Indian Ocean region already have operating tsunami warnings systems. However, in other areas of these countries and in neighboring countries, an emergency management infrastructure to receive tsunami warnings is lacking. This leaves local officials incapable of rapidly alerting the public to evacuate or to take other safety precautions. Disaster management experts assert that an emergency management infrastructure includes not just issuing tsunami warnings, but also educating indigenous people and visitors about the potential dangers in the area; clearly communicating evacuation options; adapting to potential risks by constructing public shelters; conducting periodic evacuation drills; and producing tsunami inundation maps for guiding future land-use planning.

The Bush Administration's plan for upgrading the U.S. tsunami early warning network proposed $37.5 million through 2007 to expand from six existing deepwater tsunami detection buoys to a total of 32 for the Pacific and Atlantic Oceans, Gulf of Mexico, and Caribbean Sea by 2008. The National Weather Service, which operates the program, estimated initial procurement costs to be around $24 million, excluding out-year funding for operations and maintenance. P.L. 109-13, the Emergency Supplemental Appropriations Act of FY2005, has provided for procuring, deploying, and maintaining a comprehensive U.S. tsunami early warning network. In the 109th Congress, other legislation would support long-term operations and maintenance and add public education and adaptation. Administration officials and some in Congress consider an upgraded U.S. system the first step toward building a global capability.

Although the United States' costs alone could run into millions of dollars for instrumentation and maintenance, some suggest the benefits would far outweigh the costs. Others have questioned whether the risks of tsunamis outside the Pacific Basin justify the investment. To share costs, international science agencies have suggested that global or regional warning networks could be built upon ocean data collection systems, marine data buoys, tide gauge networks, regional coastal and ocean observation networks, and global telecommunications systems. A global warning network would be most useful in countries that also have expansive national emergency management capability. This report is updated as warranted.

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Introduction

Recently, numerous congressional inquiries have posed questions about the possibility of tsunamis occurring in U.S. coastal areas; the extent to which these areas are currently monitored; how tsunamis can be detected; and whether there is a national capacity to issue evacuation warnings for tsunamis.[1] These concerns stem from the December 26, 2004, tsunami triggered by an underwater earthquake off the west coast of northern Sumatra in Indonesia. That earthquake was measured at M_w 9.0.[2] The ensuing tsunami devastated many coastal areas around the northern Indian Ocean, and caused and economic upheaval in other areas. International disaster agencies estimate that as many as 300,000 people may have lost their lives.

On January 5, 2005, the House Science Committee, House Coastal Caucus, and House Oceans Caucus co-sponsored a briefing organized by the U.S. Geological Survey (USGS) of the Department of the Interior. The purpose of the briefing was to consider the possible implications of the Indian Ocean tsunami for the United States. Experts from USGS and NOAA delivered presentations on the circumstances surrounding that tsunami disaster, and discussed current capabilities for monitoring, detection, and early warning around the globe.[3]

The National Oceanic and Atmospheric Administration (NOAA) of the U.S. Department of Commerce and various international science agencies have indicated that there were few, if any, tsunami early warning systems monitoring the Indian Ocean on December 26, 2004. However, nations bounded also by the Pacific Ocean, including Australia and Indonesia, had tsunami early warning systems monitoring the Pacific shores where they perceived the greatest threat.[4] Because of the geographic

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[1] A tsunami is a seismic sea wave (or a series of waves) usually generated by an underwater earthquake or landslide, but occasionally is caused by volcanic eruption or major landslide *into* the ocean. Tsunami is translated from Japanese as "harbor wave".

[2] M_w, the moment of magnitude, is a way to measure the force of an earthquake's total seismic energy released as a function of rock rigidity in the fault, the total area of contact where friction occurs, and the amount of slippage (or displacement). It is used for earthquakes greater than M8.2 on the Richter scale.

[3] Presenters at that briefing included, David Applegate, Science Advisor for Earthquake and Geological Hazards at the USGS; General David Johnson, Assistant Director of NOAA's National Weather Service; Gregg Withee, Assistant Director for NOAA Satellite and Information Services; and, Eddie Bernard, Associate Director of NOAA's Pacific Marine Environmental Laboratory (teleconferencing from Seattle, WA).

[4] General David L. Johnson, "NOAA Tsunami and Natural Disaster Information," Jan. 5, (continued...)

proximity of many settlements to where the tsunami was generated, and an inability to receive tsunami warnings rapidly, some have concluded that for people on Indonesia's Indian Ocean shores, emergency communications were useless in many cases. In other cases, it was found that indigenous people and tourists were not educated about the possible dangers of tsunamis; they were not aware of the physical warning signs of an onset of a tsunami; and local officials did not have alternative procedures for issuing evacuation alerts, if "lifelines" were disrupted, included in regional emergency plans.[5]

On January 29, 2005, the House Committee on Science, and on February 2, 2005, the Senate Committee on Commerce, Science, and Transportation, held hearings about providing expanded tsunami early warning protection for the United States and its possessions. Legislation recently introduced by Senator Lieberman of Connecticut (S. 34) and Senator Inouye of Hawaii (S. 50), among others, would provide for a rapid U.S. response to upgrade existing capacity for warning in the Pacific, and expand this capacity to the Atlantic, Gulf of Mexico, and Caribbean Sea. Senator Inouye's bill is closely aligned with the Administration's proposal, released on January 14, 2005, but also addresses social issues such as disaster education and local emergency preparedness. (See "Congressional Action," below.)

Although most deadly tsunamis have occurred historically in the western Pacific Ocean, there are examples of recorded events in the North Atlantic. In 1692, a tsunami generated by massive landslides in the Atlantic Puerto Rican Trench reached Jamaica's coast, causing an estimated 2,000 deaths. In 1775, a tsunami struck in the eastern Atlantic Ocean on the coast of Portugal, killing an estimated 60,000 people. More recently, in 1929, a tsunami generated in the Grand Banks region of Canada hit Newfoundland, killing 51. It was the third lethal tsunami for Canada's Atlantic Coast within 150 years.[6]

Proposals for International Tsunami Early Warning Systems

Currently, most experts agree that considerable challenges must be overcome to establish an extensive tsunami early warning network in the Indian Ocean and elsewhere. In some respects, developed nations that currently have the resources and capability to establish their own regional emergency management networks have been able to avoid some of these challenges.

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[4] (...continued)
2005 House briefing.

[5] Lifelines are emergency response services, hospitals, other care facilities, energy and water delivery systems, telecommunications, and electronic commerce. See U.S. Congress, Senate, Committee on Commerce Science and Transportation, report on S. 910, the Earthquake Hazards Reduction Act, S.Rept. 105-59, July 30, 1997, p. 3.

[6] Statistics on deaths resulting from tsunamis were compiled by CRS from online sources, and include data from the Tsunami Laboratory of Novosibirsk, NOAA's National Geophysical Data Center, the University of Southern California, Tsunami Research Group, and others. See [http://geology.about.com/library/bl/bltsunamideathtable.htm], visited Jan. 11, 2005.

Challenges. Few nations would question that development of an international system with a capability for regional and local tsunami warnings will require involving many nations with widely varying technological capabilities and financial resources. Reports indicate that political leaders expect that most of the responsibility for paying for such a system will likely fall on the wealthiest nations. The costs of procuring, operating, and maintaining instruments and platforms, and the challenge of obtaining international cost sharing, are likely to be the most critical factors for sustaining a long-term international effort for global tsunami detection and warning.

International science agencies have called for an inventory of existing global capacity for tsunami monitoring, detection, and warning systems to use as a baseline from which to determine what may still be needed for an international warning network. U.S. policy experts also have suggested that technological challenges and possible national security issues could arise with a global system, including multinational sharing of international telecommunication networks and international standardization for tsunami warning instrumentation on data platforms. In addition, some intelligence experts suggest that some data collected could be considered sensitive and perhaps compromising to U.S. or other nations' intelligence-gathering operations. Also, the Assistant Director of NOAA Satellite and Information Services has noted that some nations, including India, maintain proprietary rights to all of their real-time satellite data. Some of these data, he asserted, could be important for tsunami detection in the Indian Ocean, and also for post-disaster damage assessment.[7]

Proposals. On January 6, 2005, the United Nations proposed an international effort to develop a tsunami early warning capacity for nations bounding the Indian Ocean. That effort would be led by the UNESCO Intergovernmental Oceanographic Commission (IOC). Also, Australian, Japan, Thailand, and India have announced initiatives to monitor their own Indian Ocean coastlines, in addition to providing humanitarian aid for the region.[8] (For information on other types of foreign assistance proposed for the areas affected by the tsunami, see CRS Report RL32715, *Indian Ocean Earthquake and Tsunami: Humanitarian Assistance and Relief Operations*, by Rhoda Margesson.)

International science ministers finalized plans for a global observing system in Brussels, Belgium February 15, 2004. That system would be the backbone on which a regional tsunami early warning system for the Indian Ocean would be built. The United States is not expected to provide details of its commitment to the internationally sponsored global tsunami early warning network prior to the convening of the G-8 summit in July 2005. Experts from Indian Ocean countries affected by the December 26, 2004 tsunami and other countries met at the UN Intergovernmental Oceanographic Commission (IOC) of UNESCO, in Paris, France, March 3-8, 2005, to plan a coordinated tsunami early warning system for the Indian Ocean and to review countries' financial commitments. The Assistant Director General of UNESCO, Executive Secretary of the IOC, chaired the meeting.[9]

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[7] Gregg Withee, Jan. 5, 2005 House briefing, by USGS and NOAA.

[8] Idem.

[9] For a review of that meeting, a schedule of subsequent meetings, and ongoing activities,
(continued...)

Some Members of Congress proposed development of a "global" tsunami detection and warning system in the aftermath of the Indian Ocean disaster. Representative Pallone was the first to call for establishing a tsunami detection and warning network for the U.S. Atlantic coast, the Gulf of Mexico, and the Caribbean Sea.[10] However, others question whether the risk for a tsunami on the U.S. Atlantic coast would justify such expenditures. In response, NOAA scientists have asserted that the Puerto Rican Trench, which is the deepest point in the western Atlantic Ocean, should be of great concern.[11] As noted above, massive landslides and sloughing have occurred on the North American continental shelf, generating deadly tsunamis. One U.S. Atlantic coast state, New Hampshire, already has an emergency contingency plan for tsunamis, and a clearinghouse for information about historical tsunami disasters.[12] Some states on the Pacific coast have had plans in effect for at least 50 years.

Bush Administration Plan. On January 14, 2005, the White House Office of Science and Technology Policy (OSTP) announced the Bush Administration's plan for an improved tsunami warning and detection system for the United States.[13] That plan initially includes procuring and deploying a total of 32 dedicated tsunami warning and detection buoys by mid-2007, to provide better coverage for tsunami detection in the Pacific and Atlantic Oceans, Gulf of Mexico, and Caribbean Sea. (See **Figure 1**, below.) The President would commit $37.5 million over the next two years to implement the plan. The Director of OSTP noted the system would "ultimately include the Indian Ocean."[14] Partial funding for the President's proposal was approved in the emergency supplemental appropriations for FY2005.[15] Plans are for the National Science and Technology Council (NSTC) to release to release a detailed implementation plan later this year.[16]

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[9] (...continued)
see the IOC website at [http://ioc.unesco.org/indotsunami], visited June 1, 2005.

[10] *Congressional Record*, Jan. 4, 2005: H40.

[11] Jan. 5, 2005 House briefing,.

[12] State of New Hampshire, "Disaster Plan 409," Sect. II, Geological Hazards, Seismic Hazards, at [http://www.nhoem.state.nh.us/mitigation/state_of_new_hampshire.asp], visited Jan. 11, 2005. See also "Is your Community Ready for the Next Tsunami," National Weather Service Tsunami Ready program, at [http://tsunami.gov], visited Jan. 11, 2005.

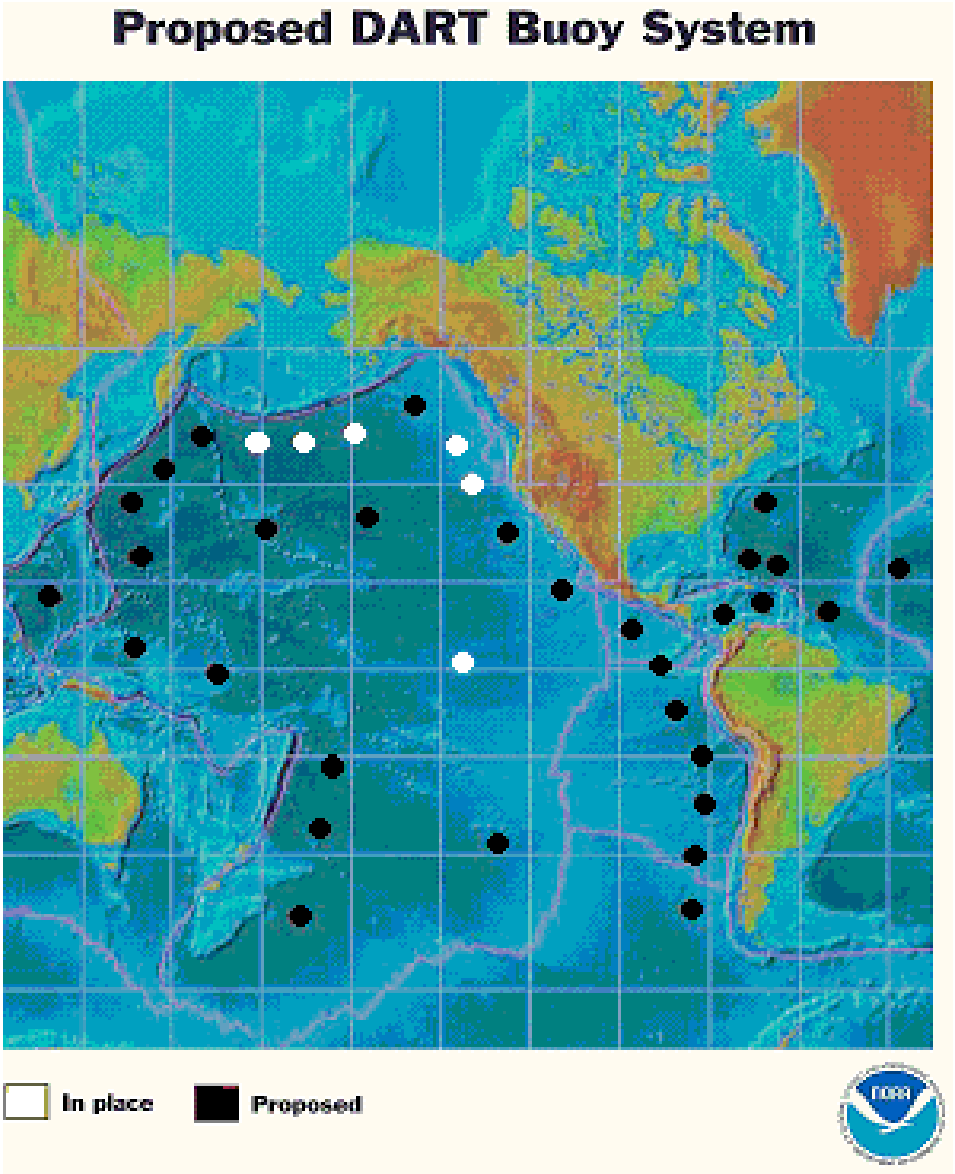
[13] U.S. Office of Science and Technology Policy, "U.S. Announces Plan for Improved Tsunami Detection and Warning System," press release, *OSTP News*, Jan. 14, 2005. See also Eli Kintisch, "South Asia Tsunami: U.S. Clamor Grows for Global Network of Sensors," *Science*, vol. 307, Jan. 14, 2005: 191.

[14] John H. Marburger, Director of Office of Science and Technology Policy, "Testimony," *Tsunami Preparedness*, hearing before the U.S. Senate Committee on Commerce, Science, and Transportation (Feb. 2, 2005). Hereafter, "Senate Commerce, Tsunami Preparedness hearing," available at [http://commerce.senate.gov/hearings/witnesslist.cfm?id=136].

[15] U.S. Congress, House Committee on Appropriations, "Communication for the President of the United States Transmitting a Request for Supplemental Appropriations ... Including Tsunami Relief and Reconstruction," H.Doc. 109-9, Feb. 15, 2005 (GPO, Washington: 2005).

[16] Personal communication with an OSTP official on the NSTC on June 1, 2005.

Figure 1. U.S. Proposal for Tsunami Detection/Warning System



Source: National Oceanic and Atmospheric Administration, from "U.S. Announces Plans for an Improved Tsunami Warning and Detection System" (modified by CRS for contrast), at [http://www.noaanews.noaa.gov/stories2005/s2369.htm], visited Jan. 18, 2005.

P.L. 109-13, Emergency Supplemental Appropriations for FY2005. The conference report on H.R. 1268 (H.Rept. 109-72, Div. A of the Emergency Supplemental Appropriations Act for Defense, the Global War on Terror, and Tsunami Relief, 2005) stated that NOAA's National Tsunami Warning Program, managed by the National Weather Service (NWS), would receive a total of $25.4 million. Conferees agreed to $7.1 million for NOAA's Operations, Research, and Facilities (ORF) account for NWS to proceed with developing coastal inundation maps and provide community outreach and preparedness programs (tsunami education and training). A portion of the funding would be used to upgrade the

Alaska tsunami warning center and to establish an international regional warning center in Hawaii. NWS would hire additional personnel at U.S. tsunami warning centers to monitor USGS earthquake alerts and issue tsunami warnings around the clock.

Conferees also reported another $10.2 million for NOAA's Procurement, Acquisition, and Construction (PAC) account. PAC funding would be used to acquire 35 new DART buoys for the Pacific and Atlantic Oceans, the Gulf of Mexico, and the Caribbean Sea, which would provide several new data points for observing ocean conditions at depth. In reference to the Global Environmental Observation Systems of Systems (GEOSS) initiative, conferees encouraged NOAA "to develop buoys with capabilities beyond the single purpose of tsunami reporting."

Finally, $8.1 million was reported for USGS's National Earthquake Information Center (NEIC) in Golden, CO. The NEIC would upgrade the existing Global Seismic Network (GSN), so more of its instruments could relay real-time earthquake data; currently 80% of the 127 instruments have that capability. GSN data are used at the NWS warning centers to determine the potential for tsunami generation after an underwater earthquake or other geological disturbance. The Alaska warning center models the intensity and possible tracking of the large waves and, in turn, issues warnings to regional emergency managers. The President signed H.R. 1268 into law as P.L. 109-13 on May 11, 2005.

Local Warnings and Emergency Communication. NOAA's Director of the National Weather Service, Brig. Gen. David L. Johnson, USAF (Ret.), and others, have emphasized that in addition to the capacity to monitor and detect possible tsunamis, a telecommunications infrastructure for issuing tsunami warnings (such as that presently in place in the Pacific Ocean) is critical for the Indian, Atlantic, and far Pacific Ocean populations. He noted that NOAA's responsibility for tsunami warnings terminate when those emergency communications are delivered to international emergency management officials. He added that in the United States, forecasts and warnings of severe weather are also picked up and distributed by local emergency managers and the media, after they are issued by local and regional NWS weather forecast offices.[17] In some nations, there are varying capabilities for relaying public emergency warnings, especially locally. In some regions these capabilities are inadequate or non-existent.

A Global Tsunami Warning Network? Addressing international tsunami detection and warning capabilities, NOAA's Administrator, Admiral Lautenbacher, has promoted development of an international Global Earth Observing System of Systems (GEOSS), an initiative that is supported by President Bush. Billed as "an excellent example of science serving society," GEOSS would be built from existing data collection platforms, and would use the telecommunications capabilities of other observation systems and communication networks currently operating around the world. One of these networks would be the International Global Ocean Observing System (IGOOS), another, Argo (climate monitoring) floats. (See "U.S. Operations

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[17] Brig. Gen. Jack Kelly, Jr., former NWS Director, and present Deputy Administrator for NOAA, "Testimony," Senate Commerce, Tsunami Preparedness hearing.

and Research," below.) Through GEOSS, IGOOS would help to build a global tsunami detection and warning capacity.[18]

U.S. and international science ministers composing the "Group on Earth Observation" met February 16, 2005, in Brussels, Belgium, and adopted a 10-year implementation plan for GEOSS. The European Union hosted the event, with 60 other countries. Details about international funding commitments, and a United States role in the global tsunami warning network, are not likely expected until the G-8 Summit convenes in July 2005.[19] However, experts from Indian Ocean countries affected by the December 26, 2004 tsunami, and other countries, met in early March to plan development of a coordinated tsunami early warning system for the Indian Ocean and to reaffirm benefactor countries' financial commitments.

A number of international science agencies and nongovernmental organizations generally support the Bush Administration proposal for a U.S. tsunami warning system, and have called it "a good start." Some social scientists argue for "institutionalizing" a strong public education component, in whatever legislation would implement the Administration's plan or otherwise be introduced in Congress for similar purposes.[20] The public education initiative envisioned includes local authorities as the developer and deliverer of disaster education activities; encourages (federal) interagency partnerships and an established presence in the community; supports adaptation as an alternative approach to disaster management; and promotes low-tech, high-impact solutions for local emergency management.[21]

Congressional Action

Some Members of Congress have introduced bills to expand existing tsunami early warnings networks globally. A majority of this legislation emphasizes expediting expanded coverage for the United States and its trust territories. Similar to the Bush Administration proposal, most legislation calls for domestic needs to be met before international commitments are made. Also, negotiations are recommended through established international diplomatic channels to deliberate national roles and responsibilities for a global warning network.

S. 34 (Lieberman)/H.R. 499 (Shays). S. 34, the Global Tsunami Detection and Warning System Act, was introduced on January 24, 2005, and referred to the Senate Committee on Commerce, Science, and Transportation.[22] This bill addresses

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[18] Gen. David Johnson, Jan. 5, 2005, House briefing. For more information on ocean observing systems, see U.S. Congress, House Resources Subcommittee on Fisheries, Conservation, and Wildlife, *Status of Ocean Observing Systems in the United States*, oversight hearing, serial no. 108-102, July 13, 2004 (Washington: GPO, 2005).

[19] John Marburger, Senate Commerce Tsunami Preparedness hearing, Feb. 2, 2005.

[20] Eileen Shea, Project Coordinator, East West Center, Honolulu, HI), "Testimony," Senate Commerce Tsunami Preparedness hearing, Feb. 2, 2005, available at [http://commerce.senate.gov/hearings/testimony.cfm?id=1361&wit_id=3955], visited Feb. 3, 2005.

[21] Ibid.

[22] Associated Press, "Hill Eyes Tsunami Warning System — Lieberman calls for Global (continued...)

U.S. tsunami early warning capabilities and deficiencies. It also recommends cooperative efforts with established international agencies to develop regional tsunami warning and emergency management capabilities for coastal communities around the globe. In addition, S. 34 encourages an inventory of existing international capabilities, but it is primarily focused on the institutional needs of developing a global warning network, and what might be an appropriate U.S. contribution. S. 34 authorizes $30 million for NOAA in FY2005 to expand the existing Pacific network and add coverage for the Atlantic and Gulf of Mexico/Caribbean Sea. Also, $7.5 million is authorized for each of FY2006 through FY2012 to operate and maintain the (U.S.) system. It directs the Secretary of Commerce to work with the Secretary of State and the Department of the Interior (through USGS) to convene an international conference to seek agreement on a U.S. contribution to a global tsunami warning network, including funding. H.R. 499, a related bill, was introduced on February 1, 2005, and referred to the House Committees on International Relations and Resources. This bill also provides for the development of global tsunami detection and warning systems to improve communication of tsunami warnings to all nations potentially affected. On February 9, 2005, H.R. 499 was referred to the Subcommittees on Fisheries and Oceans and Energy and Minerals.

S. 50 (Inouye). The Tsunami Preparedness Act of 2005 was introduced on January 24, 2005, and referred to the Senate Committee on Commerce, Science, and Transportation. The bill directly supports the Bush Administration's proposals for an expanded U.S. tsunami early warning system, and similarly proposes to eventually assist other nations in an international endeavor to build a global capacity. However, S. 50 goes further, requiring dissemination of U.S. tsunami information and research findings, and facilitating technology transfer for tsunami hazard mitigation efforts. To that end, S. 50 establishes a U.S. multi-agency task force that includes NOAA, the Federal Emergency Management Agency (FEMA), USGS, and the National Science Foundation (NSF). NOAA would be directed to provide assistance for global tsunami warning efforts through involvement with establishing an international earth observation system (GEOSS). Section 8 of the bill authorizes $35 million for "each of fiscal years 2006 though 2012, to carry out the Act."[23]

On February 2, 2005, the Senate Subcommittee on Disaster Preparedness held hearings on S. 50. The bill's author noted that S. 50 could be "effective in educating populations at risk" for tsunami disasters. He also noted that S. 50 considered sociological need as well as tsunami detection and warning, which he stated would require NSF's contribution. NOAA would be authorized to receive reimbursement of cash or services in kind from international agencies it might assist in developing a global warning network. On March 10, 2005, the full committee marked up S. 50, adopting Senator Inouye's amendment in the nature of a substitute bill. Senator Ted Stevens, committee chair, stated that S. 50 would require Congress to be notified if a (DART) buoy stops functioning, so that a replacement could be deployed. Also, the measure would authorize $5 million annually for an "integrated coastal vulnerability and adaption program." An international Tsunami Warning Center to

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[22] (...continued)
Net," *Washington Times*, Jan. 7, 2005, p. A10.

[23] *Congressional Record*, Jan. 24, 2005, p. S328.

monitor warnings in the Pacific would be established to disseminate information. S. 50 (amended) was ordered to be reported favorably to the full Senate on March 10, 2005. A written report on S. 50 was issued in April 19, 2005 (S.Rept. 109-59).

S. 361 (Snowe)/H.R. 1584 (Curt Weldon). S. 361, the Ocean and Coastal Observation Systems Act of 2005, was introduced on February 10, 2005, and referred to the Senate Committee on Science, Commerce, and Transportation. This bill develops a U.S. capacity "to monitor a range of ocean conditions and quickly assess ocean-based threats, including tsunamis...."[24] Through NOAA, S. 361 proposes broader public access and facilitation of timely public warnings of hazardous ocean conditions. It authorizes "such sums as may be necessary" for each of fiscal years 2006 through 2010, of which least half of the amount is to be used to implement regional ocean and coastal observing systems. Funding would be available until expended. The measure was marked up on March 10, 2005, and reported favorably to the full Senate without objection. On April 19, 2005, the Committee on Commerce, Science, and Transportation reported S. 361 without amendment (S.Rept. 109-60). Introduced on April 12, 2005, H.R. 1584, a related bill, would develop and maintain an integrated system of coastal and ocean observations for the nation's coasts, oceans, and Great Lakes, to improve warnings of tsunamis and other natural hazards, to enhance homeland security, to support maritime operations, and for other purposes. The bill was referred to the House Committees on Resources and Science. On May 6, 2005, executive comment was requested from the Department of Commerce.

H.R. 396 (Menendez). The Early Warning and Rapid Notification Act of 2005 was introduced on January 26, 2005, and referred to the House Committee on International Relations. This bill focuses on the sociological and institutional needs for developing tsunami warning systems in foreign countries. The legislation emphasizes four components of a proposed program to be established through the U.S. Agency for International Development (AID) consisting of: (1) expansion upon prior knowledge of risks faced by communities; (2) technological monitoring of hazards; (3) delivery of understandable warnings to those at risk, and (4) knowledge and preparedness of how to act when threatened by disasters. This bill addresses *all* disasters; however, the Indian Ocean tsunami is cited as one of the primary reasons for its introduction. H.R. 396 would improve lines of international communications for delivery of disaster warnings, by identifying impediments in U.S. and foreign government policies. It identifies the U.N. International Early Warning Program as the appropriate institution to undertake that task. It would authorize $10 million annually for FY2006 through FY2010 to develop an effective global public warning capability; establish the necessary communications infrastructure; provide technical expertise and training; and launch public education campaigns to minimize the loss of life and property. Further, it calls for employing emerging technologies, such as wireless communications, for emergency warning systems in United States territories and in international locations.

H.R. 465 (Faleomavaega)/H.R. 882 (Boehlert). On February 1, 2005, H.R. 465 was introduced "To Provide for the Establishment of a Tsunami Mitigation

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[24] Statement introducing S. 361, *Congressional Record*, Feb. 14, 2005: S1293-S1294.

Program for all United States Insular Areas," and was referred to the House Committee on Resources. The bill establishes a tsunami hazard mitigation program within NOAA for all U.S. insular areas. Also, it requires NOAA to perform tsunami hazard assessment, monitoring, warning, and public education functions for the benefit of all insular areas of the United States, including American Samoa, Guam, the U.S. Virgin Islands, Puerto Rico, and the Commonwealth of the Mariana Islands. No funding authority was proposed in the legislation. On February 10, 2005, H.R. 465 was referred to the House Resources Subcommittee on Fisheries and Oceans. H.R. 882, a related bill, was introduced February 17, 2005, and referred to the House Committee on Science. It was referred to the Subcommittees on Environmental Technology and Standards on March 3, 2005.

H.R. 890 (Pallone)/S. 452 (Corzine). H.R. 890, the Tsunami Warning and Relief Act of 2005, was introduced February 17, 2005, and referred to the House Science Committee. Title I, Tsunami Warning Systems, establishes a global tsunami disaster reduction program in NOAA to upgrade U.S. and other international regions' protection from tsunamis by encouraging cooperation through the building of global observations systems (GEOSS). The bill would expand the U.S. *TsunamiReady* program, and directs NOAA and USGS to integrate seismic monitoring using the Global Seismic Network (GSN). It would also require annual progress reports. It authorizes $38 million for FY2006, and $32 million for FY2007. On March 3, 2005, H.R. 890 was referred to the Subcommittee on Environmental Technology and Standards. Introduced on February 17, 2005, S. 452, a related bill, would provide for the establishment of national and global tsunami warning systems and would provide assistance for the relief and rehabilitation of victims of the Indian Ocean tsunami and for the reconstruction of tsunami-affected countries. It was referred to the Senate Committee on Commerce, Science, and Transportation.

H.R. 1674 (Boehlert). The United States Tsunami Warning Education Act. This bill would strengthen tsunami detection, forecast, warning, and mitigation, and would be carried out by the National Weather Service. It would upgrade and expand the U.S. (warning) network for the Pacific, including U.S. territories, the Atlantic Ocean, the Gulf of Mexico, and Caribbean Sea. It also encourages cooperation between NOAA and the U.S. Geological Survey and the National Science Foundation. It would establish an international (tsunami) research program. It would improve federal, state, and international coordination for tsunami and other coastal hazards warnings and preparedness, and aid in establishing a regional tsunami warning network in the Indian Ocean. Another major theme of the legislation is providing educational and outreach activities for U.S. populations-at-risk. It also encourages mutual sharing of related data among participating countries of a "Global Tsunami and Warning Mitigation Network." H.R. 1674 authorizes $30 million for each of fiscal years 2006-2008, allocating 70% of that for operations and upgrade of the U.S. network, 20% for mitigation programs, and 10% for an international tsunami research program. In many respects, H.R. 1674 is similar to S. 50 (Inouye). Introduced on April 18, 2004, it was referred to the House Committee on Science, and marked up by the Subcommittee on Environment, Technology, and Standards on April, 20, 2005. Full committee markup was held on May 4, 2005, and the measure was ordered to be reported.

Thus far, it appears that S. 50 and H.R. 1674 are the most likely legislative vehicles Congress would act on for authorizing a long-term commitment to developing and maintaining U.S. and global tsunami warning networks.

U.S. Tsunami Programs

Currently, NOAA has a national program managed by the National Weather Service (NWS) to warn Pacific coastal areas of tsunamis, consisting of two regional U.S. tsunami warning centers in the Pacific Ocean; a cooperative program to reduce false tsunami alarm rates in the Pacific Ocean; monitoring and detection operations; tsunami research activities; and public outreach and education programs.

Tsunami Warnings. The NWS operates the West Coast/Alaska Tsunami Warning Center (WC/AKTWC) at Palmer, AK, and the Pacific Tsunami Warning Center (PTWC), at Ewa Beach, HI.

The PTWC monitors for tsunamis and issues warnings for the Hawaiian Islands, the U.S. Pacific territories, and other U.S. and international interests in the Pacific Basin. It was established in 1949, after a strong earthquake and massive landslides off the coast of southwest Alaska caused a tsunami disaster in the Hawaiian Islands hours later. The WC/AKTWC was established in 1967, after a devastating earthquake in Anchorage, AK, in 1964 caused localized tsunami damages. This center is responsible for issuing warnings to emergency managers in Alaska, British Columbia, Washington, Oregon, and California.

In 1992, NOAA launched a National Tsunami Hazard Mitigation Program (NTHMP) to address credibility of Pacific tsunami warnings, which, at that time, were being issued with a 75% false alarm rate. Local officials became concerned about the significant social upheaval and economic disruption caused by them, and whether the public would heed tsunami warnings in the future. Additionally, the NTHMP focuses on the potential that a sizable earthquake in the Pacific Northwest Cascadia Region could generate devastating tsunamis that would damage U.S. Pacific coastal regions. Additionally, it assists five Pacific states, including Alaska, California, Hawaii, Oregon, and Washington, in developing local tsunami preparedness planning through its *TsunamiReady* program. NTHMP has developed disaster models and tsunami inundation maps for many coastal communities of its current member states.[25]

NOAA is also the leader of the UNESCO International Coordinating Group for the International Tsunami Warning System in the Pacific (ICG/ITSU). Since 1965, NOAA's National Weather Service has hosted the UNESCO/IGO International Tsunami Information Center (ITIC) which supports ITSU and its member states. ITSU was first convened in 1968 and the PTWC acts as the international operational tsunami warning center for the Pacific, and currently comprises 27 member nations, most bounded by the Pacific Ocean, except for Thailand, Malaysia, and parts of Indonesia, bounded by the Indian Ocean.[26]

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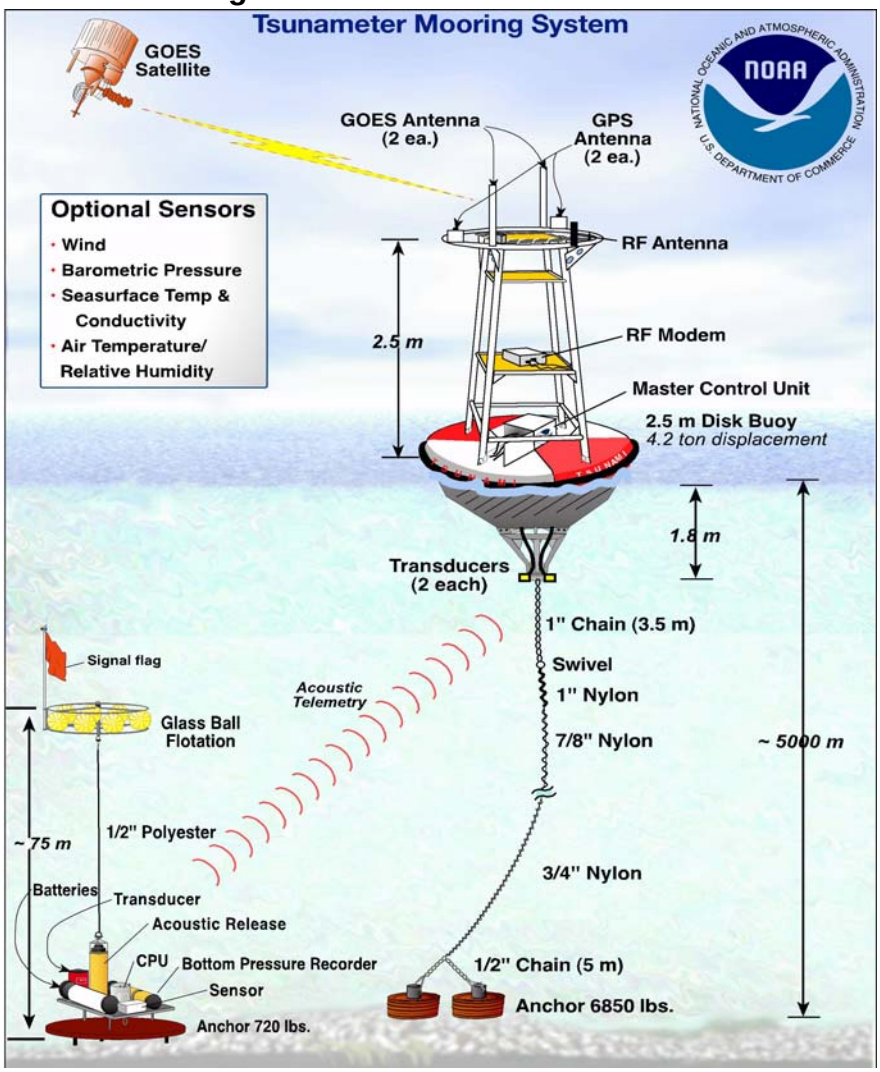
[25] Eddie Bernard of NOAA, Jan. 5, 2005, House briefing.

[26] See "International Tsunami Information Center: ITSU Master Plan," the International (continued...)

Figure 2. NOAA DART Platform



Source: National Oceanic and Atmospheric Administration, from "U.S. Announces Plans for an Improved Tsunami Warning and Detection System." See [http://www.noaanews.noaa.gov/stories2005/s2369.htm], visited Jan. 18, 2005.

U.S. Operations and Research. NOAA currently operates a network of six dedicated tsunami detection and relay stations as part of its Deep-Ocean Assessment and Reporting of Tsunamis (DART) program.[27] (See **Figure 1** for proposed locations, and **Figure 2**, above, for the components.) These are equipped to provide

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[26] (...continued)
Coordination Group for the Tsunami Warming System in the Pacific (IGC/ITSU), UNESCO/IG, at [http://www.prh.noaa.gov/itic/more_about/itsu/itsu.html], visited June 1, 2005.

[27] Hugh B. Milburn et al., "Real-Time Tsunami Reporting from the Deep Ocean," NOAA Pacific Marine Environmental Laboratory (1996), at [http://www.ndbc.noaa.gov/Dart/milburn_1996.shtml], visited Jan. 4, 2005. A seventh DART buoy owned and operated by the Chilean government is deployed off Chile's coast in South America.

an early warning capability, but NOAA officials caution these are only effective if there are emergency managers to receive their communications and, in turn, alert the public to take the necessary precautions or evacuate. The Bush Administration's proposal includes a total of 7 DART buoys for the Atlantic and 25 for the Pacific, for the first time monitoring the southwest Pacific Ocean. Also, hundreds of NWS weather buoys operating off the coasts of the United States record various meteorological data, while marine data buoys measure speed of ocean currents, temperature, salinity, and pressure change. Sea surface height (or sea level) also is measured by satellite-GPS (global positioning system) by NOAA's National Ocean Service tidal monitoring network, which is responsible for issuing warnings. All these buoys are equipped to relay data and emergency communications for navigational purposes.[28]

A proposed array of 3,000 data buoys, known as Argo floats, will be deployed in the equatorial waters of the Pacific Ocean. About a thousand of these are in place to detect conditions for El Niños and La Niñas, which are three- to seven-year climate variations that affect global weather. Argo floats might also be considered as possible platforms for situating tsunami detection instrumentation.[29] These floats have been advocated by NOAA as "the next step in global observations."[30] In the Atlantic Ocean, other possible platforms for tsunami monitoring and detection include a growing number of regional and local coastal and ocean monitoring networks in development along the coasts of Canada and the United States. Legislation to use these systems as part of a tsunami detection and warning network was introduced in the 108th Congress.[31] In the 109th Congress, Senator Snowe's bill, S. 361, would promote similar goals. (See "Congressional Action," above.)

Funding for the U.S. Tsunami Warning Program. NOAA officials estimate that the cost of adding tsunami detection instruments on Atlantic Ocean platforms, such as weather buoys, or building dedicated DART platforms, could vary depending upon the scale of the project — for example, the number of instruments to be included and the out-year costs of operation and maintenance.[32] Other

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[28] Eddie Bernard, House Science Committee briefing, Jan. 5, 2005.

[29] NOAA/Woods Hole Oceanographic Institute, *Observing the Ocean in Real-Time: Argo, a Global Array of Profiling Floats to Understand and Forecast Climate*, ed. Stan Wilson (1996). Funded in part by private academic institutions.

[30] Ibid.

[31] On January 5, 2005, Representative Curt Weldon circulated a "Dear Colleague" letter advocating the reintroduction of H.R. 5001 (108th Congress), the Ocean and Coastal Observation System Act, in the 109th Congress. This legislation promoted development of an "Integrated Ocean Observation System," to protect U.S. citizens in coastal communities from tsunamis. For further information on U.S. ocean observation systems, see U.S. House Resources Subcommittee on Fisheries, Conservation, and Oceans, *Status of Ocean Observing Systems in the United States*, Oversight Hearing, serial no. 108-102, July 13, 2004 (Washington, DC: GPO 2005).

[32] NOAA officials estimated the cost to produce the existing six experimental DART platforms, instrument them, provide a telecommunications capability, and maintain them at

(continued...)

expenditures supporting the program include funding for NOAA's U.S. tsunami-related research activities, tsunami mitigation programs, public outreach and education, the *TsunamiReady* program, and telecommunications upgrades for supporting technologies such as the USGS Global Seismic Network (GSN). (See "Related U.S. Programs," below.)

Annual funding requested for U.S. tsunami monitoring, early warning, and research is usually found in the NOAA National Weather Service (NWS) budget under Operations and Research. Additional funding may be provided for NWS in NOAA's Procurement, Acquisition, and Construction (PAC) account. Because of the December 26, 2004, tsunami in the Indian Ocean, funding was provided in the FY2005 emergency supplemental appropriations act (P.L. 109-13). Regular appropriations for these activities are provided by Title II, Department of Commerce, "National Oceanic and Atmospheric Administration," in the Science, State, Justice, and Commerce appropriations act. Prior to 2004, tsunami-related activities were funded by the NOAA Research ORF budget. (See **Table 1**, below.)

Table 1. National Oceanic and Atmospheric Administration (NOAA) Funding for U.S. Tsunami Programs

($ million)

U.S. TSUNAMI WARNING PROGRAM[a]		NTHMP[b]	TWEAK[c]	DART Buoy Acq.[d]	Strengthen Tsunami Warning Network[e]	Annual Total
FY'06	Request	2.3	0.0	6.0	3.5	**$11.8**
FY'05 Suppl.[f]	P.L 109-13	7.1	0.0	10.2	—	**$17.3**
FY'05	Approp.	4.3	2.0	0.0	—	**$6.3**
	Req.	0.0	0.0	0.0	—	**$0.0**
FY'04	Approp.	4.3	2.0	0.6	—	**$6.9**
	Req.	0.0	0.0	0.0	—	**$0.0**
FY'03	Approp.	4.3	—	—	—	**$4.3**
	Req.	0.0	—	—	—	**$0.0**
FY'02	Approp.	3.3	—	—	—	**$3.3**
	Req.	2.3	—	—	—	**$2.3**
FY'01	Approp.	3.3	—	—	—	**$3.3**
	Req.	0.0	—	—	—	**$0.0**

Source: Compiled by CRS from annual Commerce, Justice, State, Judiciary and Related Agency annual appropriations reports, and NOAA FY2006 Budget Summary.

Notes:

a. Funding for NOAA tsunami programs is not currently authorized by legislation. The last official NOAA authorization to fund NWS/NOAA Research programs occurred on October 29, 1992 in the 102nd Congress (P.L. 102-567).

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[32] (...continued)
approximately $125,000 each, but suggested there would be an economy of scale if the President's proposed total of 32 platforms for the United States in the Pacific and Atlantic Oceans were produced.

b. The Tsunami Hazard Mitigation Program has been operated out of the Pacific Tsunami Warning Center, HI, and funded since FY2004 by the National Weather Service (NWS). A major portion of the funding is divided among each of five Pacific states (AK, HI, WA, OR, and CA). The NTHMP also operates the NOAA's *Tsunami Ready* program, which provides assistance for developing local warning capacity, emergency planning, and tsunami inundation mapping.
c. Prior to FY2004, the Tsunami Warning and Environmental (Observation Center) AK conducted experimental tsunami warning system programs. In FY2004, that program was transferred to NWS along with all other tsunami-related programs.
d. Funding proposed for deployment of DART buoys in P.L. 109-13 and FY2006 regular appropriations.
e. NWS systems acquisition, in NOAA's Procurement Account. This funding would upgrade NOAA tsunami warning communications network capabilities, and global telecommunications infrastructure. It does not include $8.1 million requested for USGS's Global Seismic Network (GSN) telecommunication upgrades. (See **USGS**.)
f. Emergency Supplemental Appropriations Act, 2005 (P.L. 109-13).

Related U.S. Programs. To reduce costs of a U.S. Atlantic coast tsunami early warning system, engineers at NOAA say that it is technologically possible to modify weather and marine data buoys, such as those currently situated off the United States, to serve as platforms for mounting some tsunami monitoring and detection instrumentation. These platforms do not measure at great depths like the DART buoys, but would monitor other ocean conditions at the near-surface. The USGS and others have suggested taking greater advantage of existing international seismic monitoring stations, improving real-time data communications, and using global telecommunications networks to issue tsunami warnings to local emergency managers.[33]

The U.S. Geological Survey (USGS). USGS indirectly contributes to tsunami early warning notification. It is networked with 128 global seismic monitoring stations, including some that operate in the Indian Ocean, known as the Global Seismic Network (GSN). The GSN is managed by the Incorporated Research Institutions for Seismology (IRIS), which is a consortium of academic institutions involved with earthquake monitoring, detection, and modeling. Although the USGS does not specifically monitor for tsunami genesis, the GSN measures earthquake activity around the globe in real time. Based on where they occur, and their magnitude, the USGS makes determinations to warn NOAA of the possible onset of a tsunami. USGS officials report that currently only about 80% of the network has capability for real-time data communication. The President proposed, and Congress appropriated, $8.1 million in emergency supplemental funding for FY2005 to upgrade the real-time telecommunications capabilities of the GSN, as well as to expand the number of seismic monitoring stations around the globe.[34]

In addition, USGS geological researchers collect and analyze data on crustal deformation and ocean floor displacement, which could be precursors to earthquakes that generate tsunamis. Also, USGS topographical mapping data is used in

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[33] Kenneth B. Allen, Director of the Partnership for Public Warning, "Letter to President Bush,"Jan. 3, 2005, at [http://www.partnershipforpublicwarning.org/ppw/], visited Jan. 21, 2005. See also, Joab Jackson, "Cisco, IBM Propose Internet-Based Disaster Alert System," *Government Computer News*, Feb. 11, 2005, at [http://www.gcn.com, visited Feb. 15, 2005.

[34] Dr. Charles Groat, Director of the USGS, Feb. 7, 2006, presentation on USGS FY2006 budget held at the Dept. of the Interior. Congress appropriated $8.1 million in P.L. 109-13.

developing tsunami inundation maps for emergency managers to develop evacuation plans, as well as for government planning and private development. Although the USGS primarily monitors for seismic activity on land, it has noted that land-based operations can be as important for tsunami detection and warning, as ocean buoys.[35] For example, in coastal areas of the United States, and especially along the Pacific coast, earthquakes have generated landslides. Some of these have resulted in mass wasting of land that has entered the ocean abruptly and displaced large volumes of water. Landslides also can originate beneath the ocean and generate tsunamis. Concerns for the Atlantic coast of the United States involves a potential that a volcano in the eastern Atlantic could collapse.[36]

World Weather Watch. NOAA and other international weather agencies issue warnings of meteorological conditions that primarily affect commercial air traffic, but that also might put human lives in danger and cause significant economic disruption for global nations. The U.N. World Weather Watch (WWW) is a cooperative program organized and administered by the World Meteorological Organization (WMO).[37] NOAA plays a leadership role in the WWW, representing the United States in scientific research, weather data collection and management, and meteorological forecast and warning. The Department of State plays an important role in achieving and maintaining international agreements to sustain WWW operations globally. The WWW has an established international telecommunications network for receiving and distributing weather data and warnings, including those for the United States and its trust territories. NOAA Satellite Services manages one of three global WWW data centers for weather data analysis and forecasting, which is also an international telecommunications gateway.[38]

National All Hazards Weather Radio (NAHWR). As for local emergency management capabilities for the United States, the Department of Homeland Security and the National Weather Service are modifying the NOAA Weather Radio network as the initial infrastructure for communicating public warnings for all disasters, natural or otherwise. Over time, Congress has expanded the reach of the former

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[35] These include the USGS Advanced National Seismic System (ANSS), the Global Seismic Network, and U.S. regional networks and cooperators. See [http://earthquake.usgs.gov/eqinthenews/2004/usslav/neic_slav_faq.html], visited Jan. 4. 2004.

[36] Rossella Lorenzi, "Top World Tsunami Hotspots Detailed," *Discovery News (online)*, Jan. 11, 2005, at [http://dsc.discovery.com/news/briefs/20050110/tsunamidanger.html], visited Feb. 17, 2005. "According to Simon Day, Benfield Greig Hazard Research Center at University College London, U.K., geological evidence suggests that during a future eruption, Cumbre Vieja Volcano on the island of La Palma in the Canary Islands, off West Africa, could experience a catastrophic failure of the western flank."

[37] U.S. Dept. of Commerce, NOAA, Office of the Federal Coordinator for Meteorology, "World Weather Program," *The Federal Plan for Meteorological Services and Supporting Research: Fiscal Year 2004*, Report FCM P1-2003, Appendix B: 223-228 (Washington, DC: Oct. 2003). Other examples of international communications networks are included.

[38] NOAA's Satellite and Information Services, which operates the two U.S. WWW data Centers, reviews weather satellite data, which has since provided valuable information about the Indian Ocean tsunami. See "NOAA Scientists Able to Measure Tsunami Height from Space," at [http://www.noaanews.noaa.gov/stories2005/s2365.htm], visited Jan. 11, 2005.

NOAA Weather Radio so that this emergency telecommunications infrastructure is able to provide adequate coverage of weather services and support local forecasting and warning of extreme weather for more regions of the United States. NOAA has improved technology of weather instrumentation to increase lead time of emergency warnings; constructed transmission towers; added repeaters to expand ranges of emergency notification; and distributed individual NOAA Weather Radio receivers to the public, particularly in rural areas, so as many U.S. citizens as possible can receive disaster warnings and emergency communications. Funding for NAHWR has been about $5.5 million annually since FY2003.[39]

Conclusion

Decisions about whether and how to proceed with establishing an international tsunami early warning system for the Indian Ocean (and elsewhere) will likely be complicated for a number of reasons. One reason is because of the number of different potential international parties that would be involved with the need to coordinate data collection and warning dissemination, and a second is the funding needed to establish a tsunami warning system in that region. A third is that nations, including some in the Indian Ocean, might charge for access to critical satellite data that may help in warning potential victims and assessing damages. Senator Lieberman and others contend that the costs of acquiring those data may be well worth it, in terms of lives saved. However, others assert that the costs of accessing and using those proprietary data could be prohibitive. They are of the opinion that access to global environmental data should be provided free of charge, especially when the United States and other nations are providing disaster relief and plan on funding tsunami detection and warning activities for the region.[40]

Still others foresee challenges to standardize tsunami detection instrumentation and other related technology, and provide long-term maintenance for tsunami warning systems. There are also concerns about national security and compromising U.S. intelligence-gathering operations, if international telecommunications networks are used. That notwithstanding, some U.S. lawmakers question the actual risk of a tsunami hitting the U.S. Atlantic coast.[41] They believe the probability is low, and assert that risk should be considered when guiding development of and investment in a cooperative early tsunami warning system for the U.S. eastern seaboard. It appears that many international scientific and engineering experts view the Administration's plan for expanding the U.S. tsunami early warning network as viable. Further, the plan is backed by some Members of Congress who have introduced legislation to prepare the way for a more effective, expanded tsunami detection and warning system for coastlines of the United States and trust territories.

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[39] See NOAA Weather Radio (NWR) at [http://www.nws.noaa.gov/nwr/], visited Jan. 10, 2005.

[40] *Washington Times*, Jan. 7, 2005, p. A10.

[41] USGS, Earthquake Hazards Program, "Off W Coast of Northern Sumatra, Can It Happen in the United States?" at [http://earthquake.usgs.gov/eqinthenews/2004/usslav/canit.html], visited Feb. 17, 2005.

The President's plan for U.S. tsunami early warning capabilities proposed funding of nearly $30 million for FY2005 and FY2006, most of which was requested through the FY2005 Emergency Supplemental Appropriations Act (H.R. 1268). Congress approved $25.4 million for that purpose in P.L. 109-13. A Senate amendment to H.R. 1268 modified the Administration's proposal to include an additional $2.7 million in funding for international "in country" sociological needs for public education and adaptation strategies to complement technological needs. Many U.S. lawmakers and statesmen have indicated that greater deliberation is needed before the United States commits resources to an international effort to develop a global tsunami warning network. Foremost, they say that the United States must define its role and responsibilities.

A number of international science agencies are encouraged that U.S. domestic efforts and international planning are proceeding along similar time frames, and look forward to the development of the Global Earth Observation System of System (GEOSS), which, fundamentally, will be the United States' long-term contribution to global tsunami early warning protection.